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An experimental Sound-in-Vision distribution system: Kirk o'Shotts field trial

REPORT No. EL-22

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THE BRITISH BROADCASTING CORPORATION

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It uses SI units in accordance with B.S. document PD 5686.

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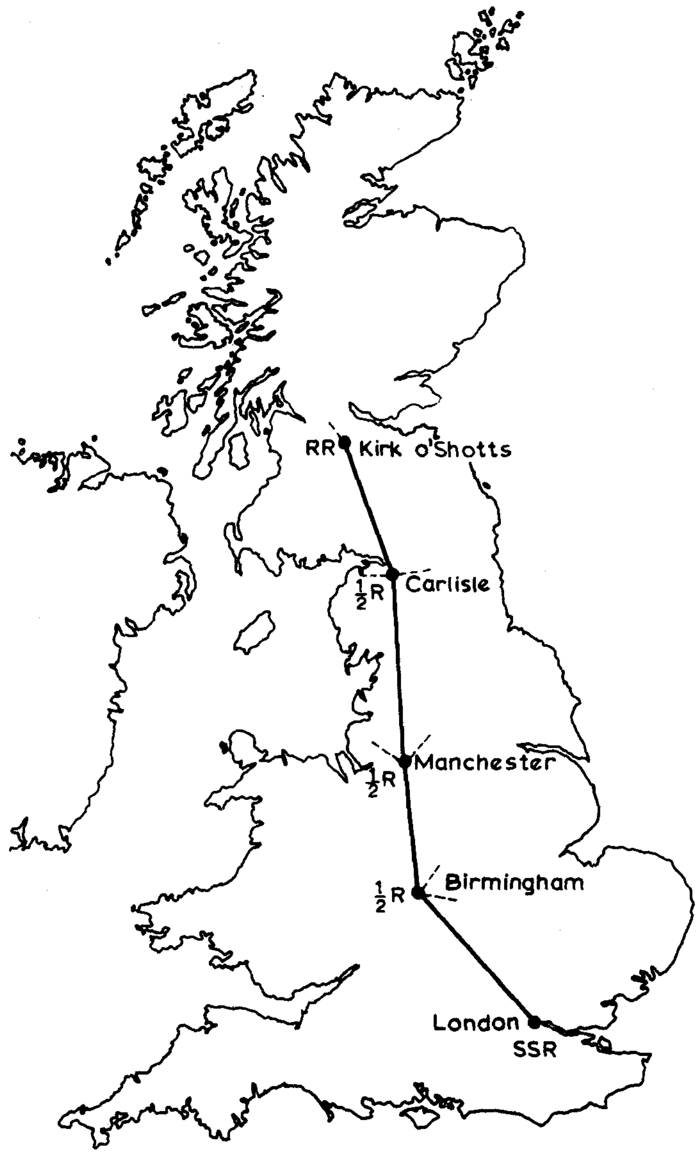

Fig. 1 - The northbound BBC 2 vision distribution chain, showing the location of Sound-in-Vision equipment

S = sending terminal
R = receiving terminal
½R = 'half separator' giving
restored vision waveform only

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SUMMARY

An experimental Sound-in-Vision system using P.C.M. signals incorporated in the synchronizing waveform has been subjected to a field trial over the BBC 2 London – Kirk o'Shotts link.

The equipment proved reliable, except for an instrumental fault causing occasional mal-functioning of the sync separator in the receiving equipment. However, sporadic disturbances of the video signal at source or on the link, manifesting themselves as 'flashing' on the picture, produced occasional 'plops' on the sound; the receiving terminal was subsequently modified to reduce these effects. Apart from this, the equipment operated correctly except when the video waveform was grossly outside tolerance. It is concluded that the Sound-in-Vision system tested, while requiring some instrumental changes, is, in principle, capable of providing a satisfactory service.

1. INTRODUCTION

The P.C.M. Sound-in-Vision system is a means whereby the line sync pulse period within a television waveform may be used to convey the accompanying sound signal from the programme source to the transmitter. A system of this type, developed by the BBC Research Department for use with 625-line television signals was demonstrated to representatives of the GPO in January 1968. Following these demonstrations it was decided to hold two field trials to assess the performance of the system in an operational environment. The first of these trials took place in March 1968 when the equipment demonstrated in January was successfully tested on the BBC 2 vision circuit between London and Crystal Palace. Further experimental equipment incorporating a number of improvements was then constructed and the system in this form (details of which are described in the Appendix) underwent a field trial during August – October 1968 on the BBC 2 vision chain from London to Kirk o'Shotts. This report gives an account of the latter trial and analyses the results obtained.

2. DESCRIPTION OF INSTALLATION

BBC 2 sound and vision signals were combined in a Sound-in-Vision sending terminal located at the Television Switching Centre, Broadcasting House, London. The combined signal travelled along the northbound vision circuit to Kirk o'Shotts where a Sound-in-Vision receiving terminal separated the two components to provide sound and vision feeds to the adjacent BBC 2 transmitter at Black Hill. Spare sending and receiving equipment was provided at London and Kirk o'Shotts respectively and an additional receiving terminal was provided at London for checking the operation of the sending equipment.

BBC 2 transmitting stations continued to be fed with sound from the normal distribution network, but it was necessary to install additional equipment at the BBC centres at Birmingham and Manchester and at the Post Office Network Switching Centre at Carlisle to ensure that the associated transmitters obtained a normal vision signal. At each of these centres therefore a simplified version of the Sound-in-Vision receiving terminal (known as a 'half-separator') was fitted; this supplied local transmitters with a restored vision signal while the composite Sound-in-Vision signal was routed further north. The location of Sound-in-Vision equipment during the field trial is shown in Fig. 1.

The BBC 2 vision signal is normally clamped at BBC Manchester. The clamping circuit used was not capable of operating in the presence of the sound pulses and had to be removed. There was some doubt whether the clamp in the receiving terminal at Kirk o'Shotts would satisfactorily handle a signal which had not been clamped since it left London, and a modified clamp, capable of handling Sound-in-Vision signals, was therefore provided by Designs Department; in the event, it was not necessary to use this. It should be observed, however, that since a clamp circuit was included in each Sound-in-Vision equipment, each transmitter obtained a vision feed that had been clamped at its local switching centre for the duration of the field trial.

3. OPERATING PROCEDURE

The transmitted vision signals were taken from the outputs of the Sound-in-Vision receiving equipment during the whole of the field trial period. For the first four weeks however, the sending terminal at London was disconnected during programme hours and Kirk o'Shotts reverted to the normal sound feed. When Sound-in-Vision signals were sent up the link the normal sound feed was available at Kirk o'Shotts as a standby.

4. MONITORING ARRANGEMENTS

Special arrangements were made with operational staff at the various centres for observing the sound and vision signals during the field trial, and details of all faults were recorded whether or not they were considered to be introduced by P.C.M. equipment. Continuous sound and vision monitoring of the radiated output of the Black Hill transmitter was carried out by staff at Kirk o'Shotts. At other dependent stations a watch was kept on the vision waveform. At London Switching Centre the outputs of the check receiving terminal were available for monitoring.

Pulse code removers (see Appendix) were provided for use in conjunction with picture monitors at BBC and GPO centres.

5. PERFORMANCE OF SYSTEM

5.1. Measured Characteristics

After the equipment had been installed measurements were carried out by Communications Department on the sound circuit thus obtained. These confirmed measurements made on the terminal equipment in the laboratory; the response/frequency characteristic was flat to within ±0·7 dB from 30 Hz to 14 kHz, and the total harmonic separation at 1 kHz was 51·5 dB for 0 dB input level and 49 dB at +10 dB input level.

Routine vision signal measurements made at the output of the receiving terminals and half separators confirmed that these were operating satisfactorily.

5.2. Performance on Programme

An analysis of fault reports obtained from Kirk o'Shotts for the period 31st August to 27th October has been completed by Transmitter I Department. During this period the system should have been operational for 692 hours; for 7·7% of this time (54 hours), however, faults in P.C.M. equipment at other centres prevented the composite signal from being available at Kirk o'Shotts. These faults, the nature and effect of which are discussed further in Section 5.3, occurred mainly during the first three weeks. The cause was thought to have been removed by 23rd September, when the equipment began to be used during normal programme hours; in the event, a number of cases were subsequently reported.

During the remaining 638 hours, degradation of the sound signal was logged for a total of 4·7 hours, i.e. at a rate of 7·4 hours per 1,000 hours. If impairments which are perceptible only on careful listening are neglected, the overall fault rate is 3·5/1,000 hours, i.e. about twice that logged on the normal BBC 1 sound feed which averages 1·8/1,000 hours.* In making this comparison, however, certain special factors have to be considered. Monitoring of the experimental P.C.M. sound at Kirk o'Shotts was much more critical than the routine observation of BBC 1 sound. Moreover the nature of the observed disturbances was different. Impairments to the BBC 1 signal often take the form of continuous interference or complete loss of sound. Disturbances to the P.C.M. sound, on the other hand, usually took the form of plops and crackles, corresponding to flashing on the picture, which occurred only sporadically during each period logged. It should additionally be noted that the BBC 1 figure excludes faults originating outside the distribution network, those occurring at the programme source, for instance. The figure relating to P.C.M. sound, on the other hand, includes the effect of disturbances caused by faults at the vision signal source or on contribution links.

Disturbances to P.C.M. sound were usually not so severe as to cause Kirk o'Shotts to revert to the normal BBC 2 sound feed. From 23rd September to the end of the trial, sound provided by the P.C.M. equipment was radiated for 97·7% of the time. Of the remaining 2·3% only 0·5%** was accounted for by plops and crackles on P.C.M. sound, the rest being due to shortages of monitoring staff at Kirk o'Shotts or equipment faults at other centres.

The Sound-in-Vision equipment worked satisfactorily with all types of originating video sources, except where these were grossly outside the normal specification, e.g. where equalizing pulses were missing (giving periodic gaps in the line-rate information) or two non-synchronous sources had been mixed, in which case a buzz-on-sound was produced.

* Comparison was made with BBC 1 sound because the information available on the performance of this system was more comprehensive than that relating to the normal BBC 2 sound distribution system.

** This rate of 5/1000 hrs was greater than that relating to the fault reports because staff at Kirk o'Shotts waited for a while after the disappearance of the fault before switching back to P.C.M. sound to assure themselves that the fault had really cleared.

Switching between non-synchronous sources caused no recorded disturbance to the P.C.M. sound signal.

5.3. Equipment Faults

5.3.1. Sync separator

The chief equipment fault occurring during the trial was caused by an occasional anomalous operation of the sync separator in the half-separator units. This produced a lifting of several of the blank lines that follow the broad pulse block. The disturbance was not apparent on picture monitors, because of field flyback suppression, but it alarmed automatic monitors at certain transmitters. All three half-separators were affected at different times. A modification to one of the sync separators was thought to have prevented further occurrences of the fault, but since this modification was made toward the end of the trial its effectiveness was not fully confirmed.

Investigations into the mechanism of this effect are in progress but it appears certain that the fault was essentially an instrumental one and is not inherent in the system adopted.

5.3.2. Stability of equipment

The circuits which reinserted sync level and blanking level after the sound pulses had been removed were known to be affected by ambient temperature changes, and pre-set controls were therefore provided. The effect of temperature changes proved to be somewhat greater than anticipated, however, and the temperature changes themselves were greater than expected at switching centres; as a result, quite frequent readjustment was found to be necessary. Further work is required to develop circuits which are more tolerant in this respect, but the problems are not thought to be insuperable.

The analogue-to-digital and digital-to-analogue convertors and the compandor operated without fault and needed no further adjustment once initially set up. In fact, apart from the failure of a fuse, the sending and receiving terminals at London and Kirk o'Shotts gave no trouble and the spare receiving terminal at Kirk o'Shotts was never used.

5.4. Effect of Video Source and Link Faults

As mentioned in Section 5.2 the majority of faults affecting the decoded sound were due to disturbances at the video signal source or on the link. In the main these caused flashing on the picture and consisted of breaks in the signal, lasting sometimes for several lines, the signal voltage being held above white or below black level for this period.

Such disturbances caused malfunctioning of several circuits in the receiving terminal, giving rise to heavy 'plops' and 'cracks'. Since the completion of the field trial, additional circuits have been introduced into the receiving terminal to minimize these effects by causing the expander gain to fall whenever the incoming signal is interrupted and to prevent some erroneous words from reaching the d.a.c. Further improvements are possible, but it is doubtful, however, whether such disturbances to the sound can be completely removed. In the context of a widespread application of Sound-in-Vision, therefore, it is desirable that interruptions to the signal be reduced to a minimum, since a fault affecting sound and picture simultaneously is probably more disturbing than one affecting the picture only.

6. LOOP TEST

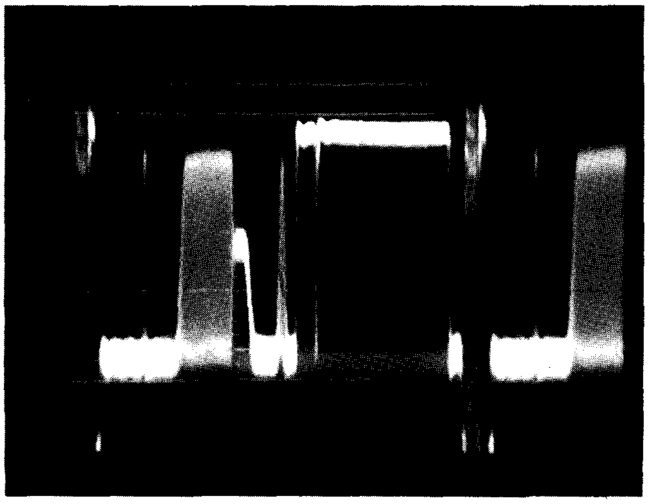
Since a complete sending and receiving terminal had been installed in London, the opportunity was taken of conducting a test over a London — Kirk o'Shotts — London loop. The equipment operated without difficulty in these conditions, the decoded sound being, as expected, indistinguishable from that obtained with the sending and receiving terminals directly connected. During part of this test a 3 MHz circuit was introduced into the Kirk o' Shotts loop; the sound continued to be satisfactorily decoded, however, even though the pulse-group eye height had fallen to about 30%. Fig. 2 shows Sound-in-Vision signals received in London during the two conditions.

7. OPERATIONAL CONSIDERATIONS

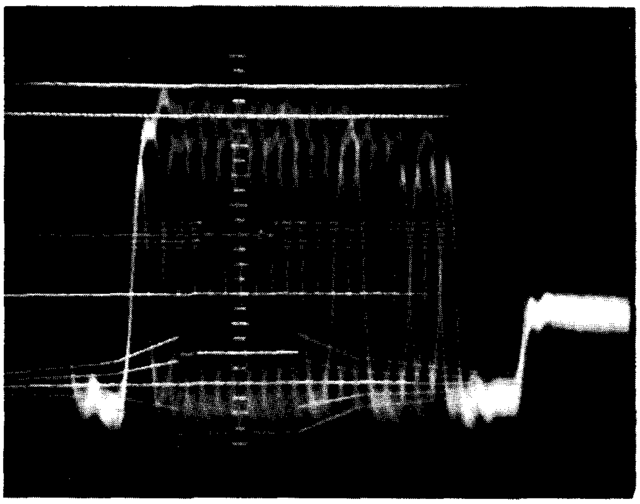
No difficulties attributable to the added P.C.M. signal were encountered by BBC or GPO operational areas in the BBC 2 network. No viewer reactions have been reported.

8. CONCLUSIONS

The field trial has established the feasibility of Sound-in-Vision for operational use in the conditions that normally apply on distribution and contribution circuits. Certain deficiencies of a minor instrumental nature have been brought to light, and the desirability of reducing 'flashing' at video sources and on vision links has been accentuated. Nevertheless, there seems no reason why equipment based on the system parameters adopted for the trial should not be entirely suitable for permanent installation.

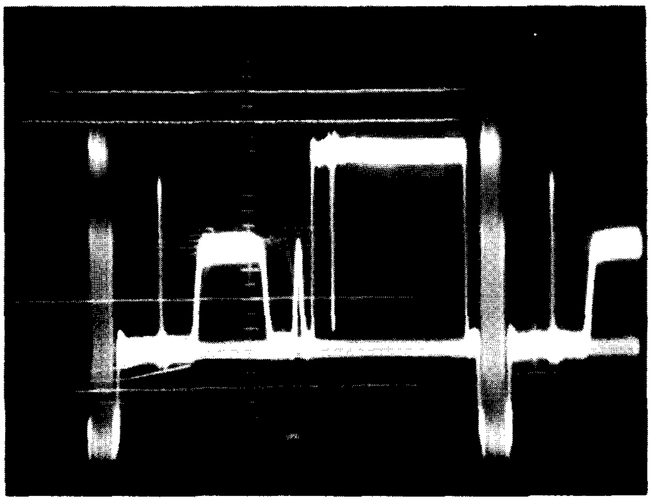


Augmented pulse and bar



Sound pulse group

(a)



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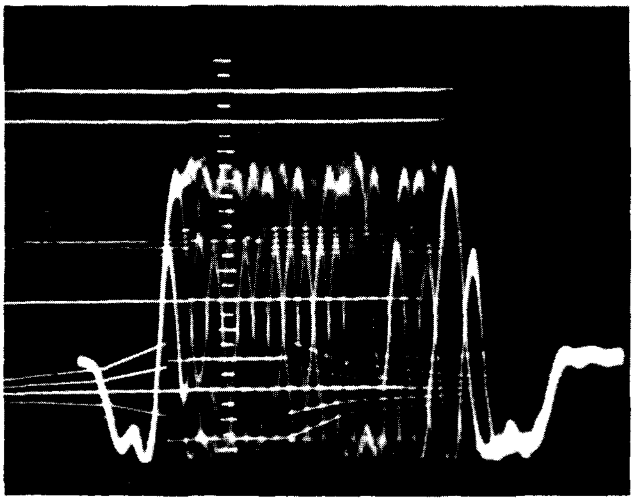

Sound pulse group

(b)

Fig. 2 - Kirk o'Shotts loop test : signals received in London

(*a*) using normal 625-line circuits (*b*) with a 3 MHz circuit connected in the chain

APPENDIX

1. THE SYSTEM

The Sound-in-Vision system to be described is essentially a form of time-division-multiplex in which the circuit is available to the sound signal for a period of 3·8 μs within each 4·7 μs line synchronizing interval, and the vision signal occupies the circuit during the remainder of the time; these 3·8 μs periods are symmetrically disposed with respect to the leading and trailing edges of the line synchronizing pulse. The leading edges of the line synchronizing pulses are preserved during transmission.

The sound signal is sampled at twice the television line frequency. This permits an audio bandwidth of 14 kHz to be transmitted. The two samples produced during each line period are converted to pulse-code modulation (P.C.M.) signals; the two groups of pulses are then delayed, compressed in time and inserted into the television waveform during the next line synchronizing interval.

The system uses a 10-digit binary code. Thus, 20 sound pulses together with a marker pulse which identifies the start of the sound pulse group, i.e. 21 pulses in all, are accommodated within each line synchronizing period. An example of the resulting Sound-in-Vision signal is shown in Fig. 3.

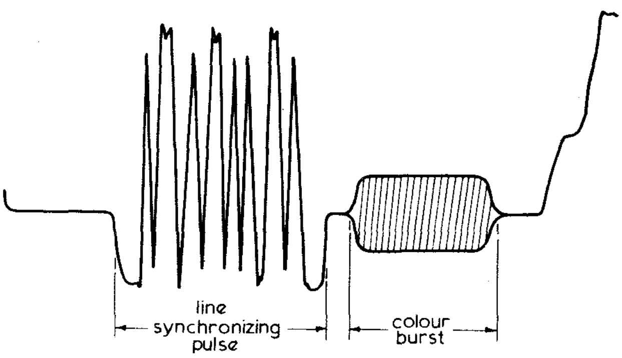

Fig. 3 - 625-line video waveform during line blanking interval, showing P.C.M. signal – consisting of a marker digit plus two ten-digit groups – inserted in line synchronizing pulse. In this example, the 21 digits form the sequence 101100101101010011010

In order to provide room for the sound pulses throughout the field blanking interval it is necessary to extend alternate equalizing pulses from 2·35 μs to 4·7 μs, but no other changes to the video signal are necessary before the sound pulses and video signal are combined.

At the receiving terminal the sound pulses are extracted and reconverted to normal audio signals and the video waveform is restored to standard form.

The sound pulses are of the 2T form, that is, a raised cosine having a half-amplitude duration of 182 ns. The complete group of pulses occupies only 3·8 μs; the spacing between the pulses is therefore 173 ns. It will be noted from Fig. 3 that two adjacent pulses combine to give an overall amplitude slightly higher than that of a single pulse; this is because with 173 ns spacing, the signal amplitude at the peak of a pulse may contain contributions from pulses immediately preceding and following it.

Pulse-code modulation and the use of high-amplitude pulses ensure that the sound signal is immune from all but the most severe interference and distortion. However, it is equally important to ensure that the presence of the sound pulses does not in any way impair the vision signal. If the phase and/or amplitude of low-frequency components is not correctly preserved by the transmission circuit, the post-line-synchronizing blanking level may be perturbed by variation in the mean level of the sound pulse groups preceding it. The pulse groups are therefore arranged within the line-synchronizing period in such a way as to reduce variation in their mean level to a minimum. The techniques used rely on the fact that substantial changes in the pulse groups representing consecutive samples of the sound signal are rare, and that the changes that do occur are most likely to affect the least significant digits. First, one of the two pulse groups within each synchronizing pulse is complemented – that is, ones are exchanged for zeros and vice versa. Secondly, the two pulse groups are interleaved, so that the *n*th digits from each group appear consecutively. Finally, the digits are arranged in the reverse of the normal order, so that the least significant instead of the most significant digits come first. Thus the complete pulse train is made up as follows: marker pulse, the two least significant digits, one of which is complemented, and so on, ending with the two most significant digits. The complementing and interleaving of digits from alternate groups provides a signal of the form shown in Fig. 3, which shows the Sound-in-Vision waveform with a d.c. input applied to the coder.

The digit train is gated into the television waveform during the 3·8 μs interval, and any noise or other irregularities present in the incoming television waveform during this period are therefore removed. The leading edge of the synchronizing pulse is, as already mentioned, left untouched because it is the main timing reference of the video waveform.

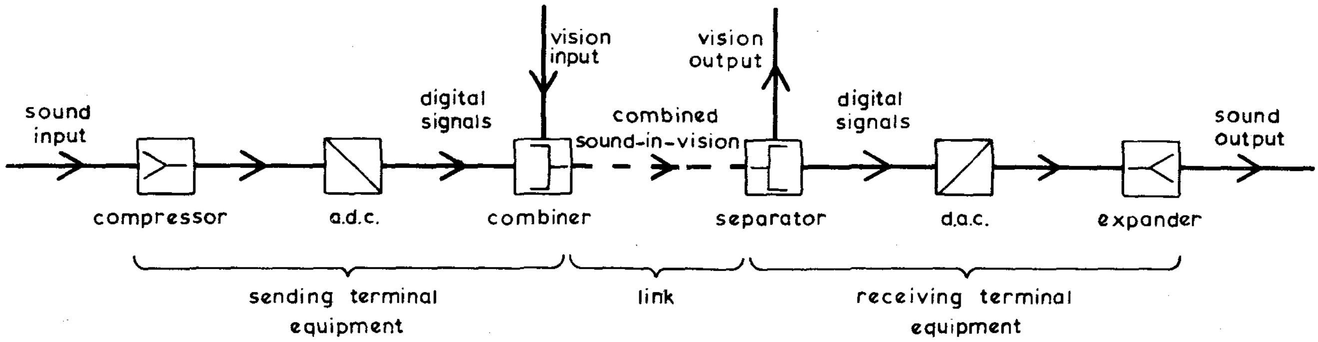

Fig. 4 - Block diagram of equipment

2. THE EQUIPMENT (Figure 4)

The compressor and expander form a syllabic companding system which ensures that the mean signal level into the analogue-to-digital converter is as high as possible. The compandor does not take the usual form, but is actuated only by high-frequency components in the signal, which have been boosted in a pre-emphasis unit. It gives an improvement of 13 dB in the signal-to-noise ratio of the P.C.M. system and thus renders the 10-digit system slightly better in this respect than one which used 12 digits but no compandor.

The analogue-to-digital converter samples the audio-frequency signal presented to it at twice-line rate, and delivers an output in P.C.M. form to the combiner unit. This unit accepts the vision signal, clamps it during the back porch, and inserts the sound pulses.

The reverse procedure is carried out at the receiving terminal. The combined Sound-in-Vision signal is fed to the separator unit from which a clamped and restored vision signal is produced. Separated sound pulses are decoded in the digital-to-analogue converter which delivers an audio-frequency signal.

Many picture monitors required at points along the link will not lock if a Sound-in-Vision signal is connected to them. A cheap and simple pulse code remover has therefore been developed which removes the sound pulses from the inputs to such picture monitors so that they may continue to be used in the normal way.

The input and output terminals of the Sound-in-Vision equipment handle sound and vision at normal levels and impedances – sound at zero level into 600 ohms, vision at 1 volt peak-to-peak into 75 ohms. The complete sending and receiving terminal equipments each occupy a height of about 356 mm (14 in.) within a normal 483 mm (19 in.) bay. Extensive use is made of integrated circuitry for the digital operations together with discrete transistor circuits for the analogue operations.

3. PERFORMANCE

The equipment will accommodate variations in line frequency up to ±1 part in 50 and will operate satisfactorily in the presence of moderate amounts of distortion on the circuit. If the maximum levels of all forms of noise and distortion permitted in two of the longest UK vision links in tandem are present simultaneously, the system will tolerate an additional 12 dB degradation (to 27 dB unweighted) in the signal-to-noise ratio. Provided that the presence or absence of sound pulses can be correctly detected, distortions and noise on the link have no effect at all on the decoded sound signal.

The P.C.M. sound channel has the following characteristics:

Response/frequency characteristic:	±0·5 dB ±0·7 dB	50 Hz to 10 kHz 30 Hz to 14 kHz
Non-linear distortion for full modulation at 1 kHz:	0·1% 0·07% 0·02%	2nd harmonic 3rd harmonic 4th harmonic
Signal-to-noise ratio (r.m.s. signal-to-r.m.s. weighted noise)	70 dB	

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